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ABSTRACT

Designed for high school electronics students, this first document in a series of six electrical learning activity packages focuses on electric motor control. An introductory section gives the objective for the activities, an introduction, and an outline of the content. The remainder of the activity book is comprised of information sheets and job sheets on topics such as (1) magnetic full voltage starters for direct current motors up to two horsepower, (2) manually reduced voltage starting for direct current motors, (3) installing a four-point starter with speed control, and (4) wiring dynamic braking circuits. Each job sheet follows a typical format that includes the objective, materials, explanation, procedure, and evaluation questions. (LRA)

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CONNECTICUT STATE DEPARTMENT OF EDUCATION
Division of Vocational Education
Hartford

# ELECTRICAL EXPERIMENTS

VT - 214 - 12 - 1

PART I

## ELECTRIC MOTOR CONTROL

CE 026 097

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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General Information 

General Principles of Electric Motor Control

Objective:

To learn some of the conditions which must be considered when selecting, designing or maintaining electric motor control equipment.

Introductory Information

Motor control was a simple problem when motors were used to drive a common line shaft to which several machines were connected, because the motor had to be started and stopped but a few times daily.

However, with individual drive, the motor has become almost an integral part of the machine and it is necessary to design the motor controller to fit the needs of the machine to which it is connected.

Thus today, in choosing motor control equipment, we must consider a great many widely differing factors in order that the motor control may function properly for the motor and the machinery for which it is designed.

Explanation:

Some of the factors with respect to the purpose of the controller which have to be considered in choosing motor controls may be enumerated as follows:

a. Starting
b. Stopping
c. Reversing
d. Running
e. Speed control

The motor may be controlled manually by an operator using one of the following devices:

a. Safety switch
b. Drum controller
c. Face plate type

The motor may be controled by remote control using push buttons.

If the motor is to be automatically controlled, the following devices may be used:

a. Float switch
b. Pressure switch
c. Time clock
d. Thermostat
e. Electric or mechanical interlock from other machines.

It may be necessary in starting and stopping to consider the following conditions to which the motor and its connected machine may be subjected:

a. Frequency of starting and stopping
b. Light or heavy duty starting
c. Fast or slow start
d. Manual stop by an operator or automatic by some automatic device
e. Smooth start
f. Quick stop or slow stop
g. Accurate stops as in landing at floor levels in an elevator
h. Frequency of reversals required

Speed control of the motor becomes essential not only to start the motor but to control its speed while running. With regard to speed control, the following conditions must be considered:

a. Constant speed
b. Adjustable speed
    1. While running
    2. Preset
c. Constant speed with variable load

With regard to the motor itself, it must be decided whether or not the following protective features are required:

a. Overload
b. Open field protection
c. Open phase protection
d. Reversed phase protection
e. Over travel protection
f. Over speed protection
g. Reversed current protection

The many automatic systems of starting and control which can be used may be divided into the following general classifications:

a. Current limiting acceleration
    1. Counter EMF or voltage drop acceleration
    2. Lockout contactor or series relay acceleration.
b. Time delay acceleration
    1. Individual dashpot relays
    2. Multicircuit dashpot relays
    3. Escapement Timing
    4. Inductive time limit relays
    5. Motor driven timers
    6. Capacitor timing

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ELECTRIC MOTOR CONTROL

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Direct Current Motor Controls

Information Sheet 1
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Magnetic Full Voltage Starter for D.C. Motors up to 2 HP

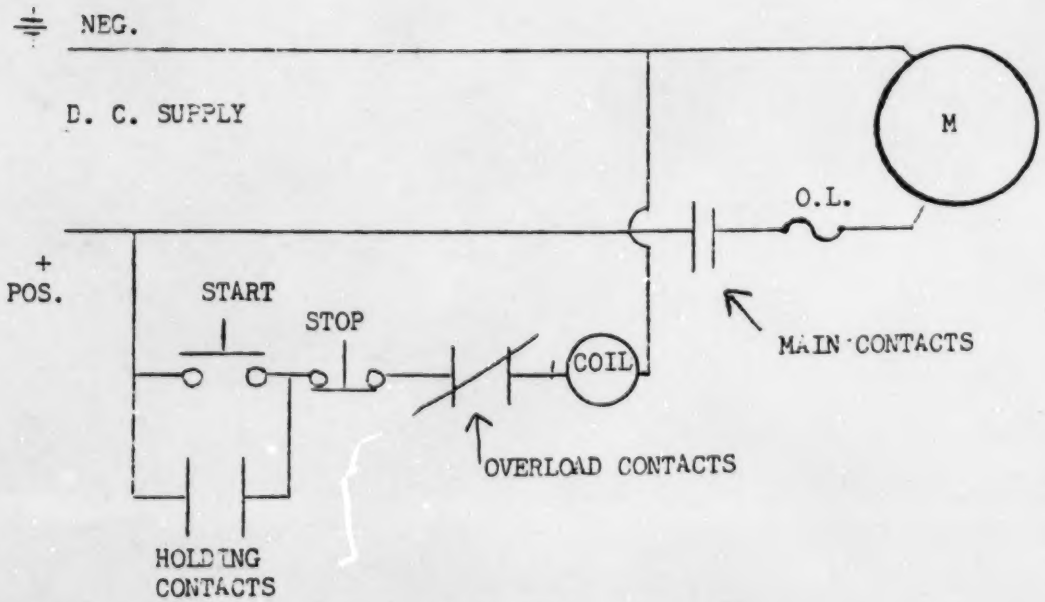
Purpose:

To understand that fractional HP and motors up to 2 HP D.C. can be started with full voltage across the motor terminals.

Explanation:

Magnetic across the line contactors for DC motor control up to 2 HP are used for starting, stopping and reversing DC motors where full voltage starting will not damage the motor or its driven equipment. A single contactor is used for simple starting-stopping: Two interlocked contactors are used in reversing starters. Applications and connections of these starters is generally the same as for AC magnetic starters. Two and three wire control circuits can be used in the operating coil circuit with push buttons or other pilot devices to provide remote or automatic operation. Running overload protection is included in the starters and undervoltage protection or undervoltage release can be provided for the motor with these starters.

Typical Wiring Diagram For Magnetic Full Voltage Starter for DC Motors up to 2 HP.



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Direct Current Motor Controls

Job Sheet 1
Page 1 of 3

# Magnetic Full Voltage Starter

## Objective:

To have student properly install and connect a D.C. full voltage magnetic starter to a motor of 2 h.p. or less, and controlled from one station start and stop.

## Materials:

A D.C. motor; a D.C. magnetic full voltage starter, one momentary push button start and stop station; disconnecting means; other materials required to complete the job, to be determined by student.

## Explanation:

An electrician is sometimes called upon to install a D.C. full voltage starter to control a D.C. motor of 2 h.p. or less. He must be familiar with the kind of starter that is required and must know the N.E.C. rulings that govern this type of installation.

## Procedure:

1. Have instructor assign motor to be controlled and classification of service. Code Art. 430

2. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent protection from feeder termination to motor. Code Art. 430

3. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C. Code Art. 310 - Chapter 9, Table 3A.

4. Submit for approval a wiring diagram showing all connections from feeder termination to motor.

5. Proceed to mount equipment in area designated by your instructor.

6. If equipment is already mounted, submit diagrams called for in Step 2 through 4 and check the existing installation for proper size equipment, conduit, wire, fuses and overload protective devices.

7. Identify all component parts of this control and explain the function of each.

8. Check the following for:
   a. Contact surfaces (i.e. clean, worn, pitted, alignment)
   b. Smooth operation of armature
   c. Proper contact tension
   d. Correct coil voltage
   e. Correct overload protection devices

f. Broken or cracked arc-chutes
g. Broken or cracked bases
h. Factory installed jumpers

9. Proceed to wire equipment and controls as per your approved wiring diagram.

10. Check motor for the following:

a. Proper voltage
b. Bearings well lubricated, if oil ring type lubrication, be sure oil ring turns freely when motor shaft is rotated.
c. Armature turns freely without squeaking or bumping.
d. Commutator free from carbon deposits, glistening but dark in color.
e. Brushes bear evenly across their whole surface with proper tension.
f. Keyed pulley is tight on motor shaft (if used).
g. Belt is adjusted to proper tension if the motor drives a machine by belting.

11. a) Check all terminal connections for tightness.
b) All splices shall be mechanically and electrically tight.

12. HAVE YOUR INSTRUCTOR CHECK the completed installation and SECURE HIS APPROVAL for energizing the circuit.

NOTE: If the instructor directs a new job, i.e., wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or the switchboard. Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any places where the work is done contrary to N.E.C. rules. The wiring must be done neatly, and the wires used must be of proper type and proper carrying capacity.

13. Energize circuit to magnetic starter.

14. Actuate starter by pushing start button.

15. Check for On and Off operation. If anything is wrong with a motor as it runs, it will make a noise that is characteristic of the trouble. When a motor runs quietly, it may be assumed to be in good condition. If the motor is noisy in operation CHECK WITH YOUR INSTRUCTOR.

16. De-energize circuit, and install a D.C. ammeter in the motor circuit, of suitable range, for the current rating of your D.C. motor. Be sure polarity is correct. This can be accomplished in most cases by removing the heater in the overload protective device and installing your meter leads at that point. BE SURE YOUR METER IS PROTECTED during the high starting current period.

17. Install a D.C. voltmeter of suitable range into the motor circuit. This can also be installed at the magnetic starter. Check polarity.

18. HAVE YOUR INSTRUCTOR CHECK your meter circuits at this time and SECURE HIS PERMISSION to re-energize the circuit.

19. Take a current reading of the motor and record.

20. Check this current value with name plate current rating of motor.

21. Take a voltage reading of the voltmeter, this reading should correspond to the voltage rating on name plate of motor. Record same.

22. Check the speed in R.P.M. of motor with the use of a tachometer and record.

23. Check this value in R.P.M with nameplate R.P.M. rating of motor.

24. De-energize circuit. Note: If there is serious disagreement in the value of the readings CHECK WITH YOUR INSTRUCTOR.

25. All data should be recorded in suitable form and turned in to your instructor for evaluation, and permission secured to disconnect the meters from the circuit.

Questions:

1. Explain in detail the operation of the D.C. magnetic full voltage starter.

2. Explain what part the holding contacts play in this starter.

3. What type of overload protection device is used in this starter? Explain how it works and protects the motor from constant overload.

4. Explain why larger motors than 2 h.p. cannot be used with this type of starter.

5. State the N.E.C. ruling on branch circuit conductors for a single motor.

6. What is the N.E.C. rule on disconnecting means for a stationary motor of 2 h.p. or less and 300 volts or less.

7. What is the required location of controller for within sight of controller location, according to N.E.C.

8. What is the basic code requirement for running overload protection for motors having a temperature rise not over $40^{\circ}$c? For motors having a temperature rise of over $40^{\circ}$c?

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Direct Current Motor Controls

Information Sheet 2
Page 1 of 3

Manual Reduced Voltage Starting for DC Motors
Three Point Starting Box Manually Operated

Objective:

1. To learn the internal and external connections for three and four terminal manual starting rheostats.

2. To discuss the specific applications for each type of manual starting.

Related Information:

Two factors limit the current taken by a motor armature from a direct current source. They are: (1) the counter electromotive force, and (2) the armature resistance. Since there is no counter electromotive force at standstill the current taken by the armature would be automatically high. Therefore, it is necessary to limit the armature current by means of an external resistor. This is done by using a starting rheostat. A starting rheostat or motor starter is described by the National Electrical Manufacturers Association as a device designed for accelerating a motor to rated speed in one direction of rotation. The primary function of a three point or four starter is to limit the current to a safe value during the starting period.

Two general constructions of faceplate starter, the three-point and four-point, are employed for shunt and compound motors. The terms indicated refer to the number of wiring terminals that are provided for connections to the motor source. In such starters a steel operating arm is fitted with a spring-loaded brass shoe that wraps over a set of contact studs as the arm is moved clockwise from the OFF to the ON position; in doing so a set of accelerating resistors is cut out as the motor comes up to speed. To minimize arcing at the contacts and to avoid a too rapid motion of the lever arm, more contact points or steps are generally used on the manual starters than with carefully adjusted and regulated automatic devices; also, the last contact stud is made larger than the others because it carries current continuously. For the smaller sizes, the resistance material is usually iron wire or some ferro-chrome-nickel alloy that resists oxidation at high temperatures while cast iron or special alloy stampings, arranged in built-up sections with properly spaced taps, are common to the larger starters. Moreover, the magnitudes of the various acceleration resistors are determined by the permissible inrush currents, between 125 and 200 per cent of rated value, and the sizes of the fuses that must protect the motor.

Explanation:

Classification of controllers involve many types but essentially they are either manually or automatically operated.

DC motors of 1/2 HP or less consume very little current and therefore can be started by placing full voltage across the motor terminals. Large DC motors cause large initial currents to flow because they have a low ohmic resistance. If full voltage is applied to a large motor while it is at a standstill, the excessive current flow may damage the motor or burn out the fuses. To start a large motor, it is necessary to place a resistance unit in series with the motor so that the starting current is reduced to a safe value. As the motor accelerates, this resistance can be gradually decreased. After the motor has reached the desired speed the resistance is no longer required because the motor is generating a voltage which is opposite to the impressed voltage, thereby preventing excessive current flow. This voltage, opposing line voltage, is called counter electromotive force. Counter EMF is at its greatest value when the motor is at full speed and is zero when the motor is at a standstill.

A three point starting box connected to a DC motor.

A three point starter sometimes called a Dial or Face Plate starter, consists of a series of contacts mounted on an insulating panel and connected to different points in the tapped resistance unit.

An arm or dial bearing is so arranged so that it can be moved across the stationary row of contacts.

After the line switch is closed, the handle is moved to the first contact. The shunt field is now connected to the line, and is at full strength. All of the starting resistance is in series with the armature. See Figure #2.

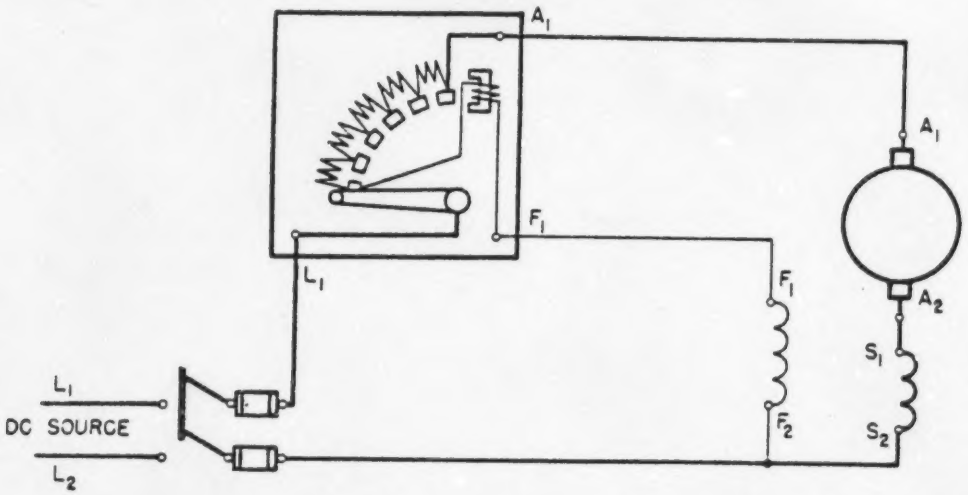
As the motor speeds up, the operator moves the handle gradually toward the last contact. This cuts out the resistance in the armature circuit and the armature is connected across the source voltage, and the magnetic holding coil holds the handle in the "on" position. The spring reset tends to return the handle to the off position. This is prevented by the magnetic pull of the holding coil. If the shunt field current became greatly less, the motor would race if the armature circuit remained connected; however, this is prevented by having the holding coil connected in series with the shunt field. Reduced current reduces the pulling force of the coil and allows spring reset to overcome the holding force of the magnetic holding coil, allowing the handle to return to the off position. This is called "no field release". Also, if the line voltage is interrupted, the holding coil releases the handle, requiring the motor to be restarted when the line voltage is restored. The three point starter gets its name from the three terminals used, one marked "L" for one of the supply lines, one marked "F" for the connection to the motor field, and one marked "A" for connection to the motor armature.

Starters are sometimes so constructed that instead of the electromagnet being made strong enough to hold the arm in the running position against the force of the spring, a catch is provided, which will engage and hold the arm after it has been manually moved to the running position. Then, if the voltage drops below a predetermined value, the electromagnet disengages the catch. This releases the arm, which is returned to the off position by the spring. The magnet coil may be connected directly across the line with a protective resistance in series, in which case it is called a low voltage

coil, or it may be connected in series with the shunt field, in which case it is called a no field coil. The coil must be designed specifically for specific motor applications if it is to be used in series with the shunt field.

These starting rheostats are not suitable for reversing or dynamic braking service. They may be used for starting series, shunt or compound motors.

Overload protection is not generally provided in starting rheostats. This protection must be provided at some other point in the motor circuit by means of fuses, circuit breakers or safety switches with thermal overload protection.




An advantage of the three point starting box is that the motor is protected from running away. An open in the shunt field circuit, or seriously weakening the shunt field will cause the starter to disconnect the motor from the line.

A disadvantage of the three point starting box is that it cannot be used for variable speed operation of a DC motor with shunt field control.

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Direct Current Motor Controls

Job Sheet 2
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# Wire a 3-Point Starting Box

Objective:

1. Understand the circuits involved in a 3 point starter connected to a DC motor.
2. Ability to properly connect a 3 point starter to a DC motor.
3. Ability to apply N.E.C. requirements to the installation.

Materials:

A 3 point DC starting box; DC motor; disconnecting means; conduit and fittings; wire or cable; overload protective device for motor used and all other necessary materials to be determined by the student.

Explanation:

Whenever a DC motor cannot be started across the line, a resistance type starting rheostat, manual or automatic must be used. This job involves the use of a 3 point starting box manually operated. Please read the information sheet on reduced voltage starting for DC motors, 3 point starting box manually operated.

Procedure:

1. Have your instructor assign motor, 3 point starting box and classification of service.
2. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent protection required from feeder termination to motor.
3. Submit for approval a wiring diagram showing all connections from feeder termination to motor. (label all parts)
4. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C.
5. Proceed to mount equipment in area designated by your instructor.
6. If equipment is already mounted, submit diagrams called for in Steps 2 through 4 and check the existing installation for proper size equipment, conduit, wire, fuses and overcurrent protective devices.
7. Check disconnects and starting box for the following:
   a. Contact surfaces (i.e. clean worn, pitted, alignment)
   b. Correct and smooth operation of moving parts (no binding)
   c. Check operation arm for spring reset (be sure arm returns to "off" position and does not remain in "run" position when holding coil is de-energized)

d. Check for correct voltage
e. Check resistance unit in starting box for opens and grounds
f. Check no field release, or low voltage release coil in starting box for continuity
g. Broken or cracked bases
h. Proper internal connections
i. Correct overload protective device for motor used.

8. Identify all component parts of this control and explain the function of each. Submit to your instructor for approval.

9. Proceed to wire equipment and control as per your approved wiring diagram.

10. Check motor for the following:

a. Proper voltage
b. Bearings well lubricated, if oil ring type lubrication. Be sure oil ring turns freely when motor shaft is rotated.
c. Armature turns freely without squeaking or bumping.
d. Commutator free from carbon deposits, glistening but dark in color (chestnut brown)
e. Brushes bear evenly across their whole surface with proper tension
f. Keyed pulley is tight on motor shaft (if used)
g. Belt is adjusted to proper tension if motor drives a machine by belting.

11. Check all terminal connections for tightness. All splices shall be mechanically and electrically tight.

12. Have your instructor check the completed installation and secure his approval for energizing the circuit.

Note:

If the instructor directs a new job - i.e. wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or the switchboard.

Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any place where the work is done contrary to the N.E.C. regulations. The wiring must be done neatly and the wires used must be of proper type and proper carrying capacity.

13. Energize circuit to 3 point starter.

14. Move the operating arm of the three point starter step by step over the contacts, waiting a few seconds on each contact for the motor speed to accelerate. If this process is performed too quickly the motor may be damaged by excessive current; if too slowly, the starting resistors may be damaged. If the motor fails to start on the first step move promptly to the second step and if necessary to the third, but no farther. If no start is made when the third step is reached, allow the starter handle to return to the off position, and look for faulty connections, overload on motor, etc.

15. If no fault is encountered in moving from the first contact to the third contact and the motor accelerates in speed, continue moving handle until the last contact is reached. At this point the holding coil retains the handle in run position.

Note:

It should be noticed at this point that when the handle is moved to the last contact point, the starting box resistance is entirely removed from the armature circuit, and that it has been gradually placed in the shunt field circuit.

This will have no effect on the performance of the motor because the resistance has a very low value in comparison to the resistance of the shunt field. Note also that the holding coil is connected in series with the shunt field. Therefore current will flow through it when the field is excited, energizing it and causing it to become an electromagnet. Thus the holding coil retains the handle in run position. Should the shunt field open for any reason, the current will stop flowing in the holding coil. Spring action will cause the handle to fall back and open the circuit to the armature.

16. With the movable arm in run position and the motor running, open disconnecting means. Movable arm should fall back to off position. This is important. If it does not, check and correct fault.

17. Re-energize circuit to 3 point starter and check starter and run operation. Be sure that the motor bearings are being properly lubricated, and that the motor is running smoothly and quietly. If the motor is noisy in operation check with your instructor.

18. De-energize the circuit and install a DC ammeter in the motor circuit. Be sure this ammeter is of suitable range for the current rating of the DC motor. This can be installed at the 3 point starter. Be sure the meter is protected during the high starting current period.

19. Install a DC voltmeter of suitable range in the motor circuit. If both lines were wired through the 3 point starting box this can also be installed at the 3 point starter.

20. Have your instructor check your meter circuits and at this time secure his permission to re-energize the circuit.

21. Repeat steps 14 and 15 and take a current reading of the motor and record.

22. Check this current value with name-plate current rating of motor.

23. Take a voltage reading of the voltmeter. This reading should correspond to the voltage rating on the name-plate of motor. Record same.

24. Check the speed in R.P.M. of motor with the use of a speed counter and record.

25. Check this value in R.P.M. with name-plate R.P.M. rating of motor.

26. De-energize circuit.
27. If there is serious disagreement in the value of reading taken and data secured from name-plate on motor, check with your instructor.
28. All data should be recorded in suitable form and turned in to your instructor for evaluation, and permission secured to disconnect meters from the motor circuit.
29. After meters have been disconnected and returned, replace any connections that may have been removed when inserting meters in the circuit.

Questions:

1. Describe the construction and operation of a three point starting box.
2. Why is it called a three point starting box?
3. Why is the holding coil of a three point starting box called a no-field release?
4. What is the function of the holding coil?
5. What type of overload protective device was used on this job? Was this device found in the three-point starter? Explain in detail.
6. What are the N.E.C. requirements in regard to the installation of starting boxes?
7. What are the N.E.C. requirements in regard to the construction of starting boxes?
8. What are the N.E.C. requirements in regard to the location of starting boxes with reference to the motor?
9. N.E.C. requires that motor starting rheostats shall be so designed that the contact arm cannot be left on intermediate segments.
   (a) Why do they make this requirement?
   (b) How was this requirement fulfilled on the starting box you used on this job?

References:

Croft - American Electrician's Handbook
National Electrical Code
Loper - Direct Current Electricity
Robert Rosenburg - Electric Motor Repair
Delmar - Electricity III
McIntrye - Electric Motor Control Fundamentals

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Direct Current Motor Controls

Job Sheet 3
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# Wire a Four Point Starting Box Manually Operated

Objective:

1. Understand the circuits involved in a four point starter connected to a D.C. motor.
2. Ability to properly connect a four point starter to a D.C. motor.
3. Ability to apply N.E.C. requirements to the installation.

Materials:

A four point D.C. starting box; D.C. motor; disconnecting means; conduit and fittings wire or cable; overload protective device for motor used and all other necessary materials to be determined by student.

Explanation:

Whenever a D.C. motor cannot be started across the line, a resistance type starting rheostat, manual or automatic, must be used. This job involves the use of a four point starting box manually operated. Please read the information sheet on reduced voltage starting for D.C. motors, four point starting box manually operated.

Procedure:

1. Have instructor assign motor and classification of service.
2. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent protection from feeder to motor.
3. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C.
4. Submit for approval a wiring diagram showing all connections from feeder terminal to motor.
5. Proceed to mount equipment in area designated by your instructor.
6. If equipment is already mounted, submit diagrams called for in Steps 2 through 4 and check the existing installation for proper size equipment, conduit, wire, fuses, and overcurrent protection devices.
7. Check disconnects and starting box for the following:
   a. Contact surfaces (i.e. clean, worn, pitted, alignment).
   b. Correct and smooth operation of moving parts (no binding).
   c. Check operating arm for spring reset (be sure arm returns to "off" position when holding coil is de-energized).
   d. Check for correct voltage.
   e. Check resistance unit in starting box for opens and grounds.
   f. Check "no voltage release" in starting box for continuity and condition.
   g. Check for broken or cracked bases.

h. Check starting box for proper internal connections, and condition of resistance tubes and wiring.

i. Check for correct overload protective device for motor used.

8. Identify all component parts of this control and explain the function of each. Submit to your instructor for approval.

9. Proceed to wire equipment and control as per your approved wiring diagram.

10. Check motor for the following:

a. Proper voltage.
b. Bearings well lubricated, if oil ring type lubrication, be sure oil ring turns freely when motor shaft is rotated.
c. Armature burns freely without squeaking or bumping.
d. Commutator free from carbon deposits, glistening but dark in color (chestnut brown).
e. Brushes bear evenly across their whole surface with proper tension.
f. Keyed pulley is tight on motor shaft, (if used).
g. Belt is adjusted to proper tension if motor drives a machine by belting.

11. Check all terminal connections for tightness. All splices shall be mechanically and electrically tight.

12. Have your instructor check the completed installation and secure his approval for energizing the circuit.

Note:

If instructor directs a new job - i.e. wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or the switchboard. Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any place where the work is done contrary to the N.E.C. regulations.

The wiring must be done in a workmanlike manner and the conductors used must be of proper type and proper carrying capacity.

13. Energize circuit to four point starting box.

Note:

If a field rheostat is used in the shunt field circuit, be sure that the resistance has been cut out of the shunt field circuit. This is important because the shunt field could be weakened to a point where the motor will tend to "run" away, and destroy itself.

14. Move the operating arm of the four point starting box step by step over the contacts, waiting a few seconds on each contact for the motor speed to accelerate. If this process is performed too quickly the motor may be damaged by excessive current; if too slowly, the starting resistors may be damaged. If the motor fails to start on the first step move promptly to the second step and if necessary to the third; but no farther. If no start is made when the third step is reached, allow the operating handle to return to off position, and look for faulty connections, overload on motor etc.

15. If no fault is encountered in moving from the first contact to the third contact and the motor accelerates in speed, continue moving handle until last contact is reached. At this point the holding coil will retain the movable arm in run position.
16. With the movable arm in run position and the motor running, open disconnecting means. Movable arm should fall back to off position. This is important. If it does not, check and correct fault.
17. If a field rheostat is used in the shunt field circuit cut out resistance in the shunt field and re-energize circuit to four point starting box and check start and run operation. Be sure that the motor bearings are being properly lubricated and that the motor is running smoothly and quietly. If it does not, check with your instructor.
18. De-energize the circuit and install a D.C. ammeter in the motor circuit. Be sure this ammeter is of suitable range for the current rating of the D.C. motor. This can be installed at the four point starter. Be sure the meter is protected during the high starting current period.
19. Install a D.C. voltmeter of suitable range in the motor circuit. This can also be installed at the four point starting box.
20. Have your instructor check your meter circuits and at this time secure his permission to re-energize the circuit.
21. Repeat Steps 14 and 15 and take a current reading of the motor and record.
22. Check this current value with name plate current rating of motor.
23. Take a voltage reading of the voltmeter. This reading should correspond to the voltage rating on the name plate of motor. Record same.
24. Check the speed in R.P.M. of motor with the use of a speed counter and record.

Note:

This should be done with field rheostat resistance cut out of the shunt field circuit.

25. Check this value in R.P.M. with name plate R.P.M. rating of motor.
26. De-energize circuit.
27. If there is serious disagreement in the value of readings taken and data secured from name plate on motor, check with your instructor.
28. All readings and data should be recorded in suitable form and turned in to your instructor for evaluation, and permission secured to disconnect meters from motor circuits.
29. After meters have been disconnected and returned, replace any connections that may have been removed when installing meters in the circuit.

Questions:

1. Describe the construction and explain the operation of a four point starting box.

2. Why is it called a four point starting box?

3. What is the function of a holding coil and why is it called a "no voltage release" instead of a "no field release".

4. What type of overload protective device was used on this job? Was this device found in the four point starter? Explain in detail.

5. What are the N.E.C. rules that apply to fuse protections for D.C. motors. State the rule, article number, and section number.

6. What are the N.E.C. requirements in regard to the installation of motor starting rheostats?

7. What are the N.E.C. requirements in regard to under voltage release, D.C. motors?

8. N.E.C. requires that motor starting rheostats shall be so designed that the contact arm cannot be left on intermediate contact segments.
   a. Why do they make this requirement?
   b. How as this requirement fulfilled on the starting box you used on this job?

References

Swoope's Lessons in Practical Electricity
Croft - American Electrician's Handbook
National Electrical Code
Loper - Direct Current Electricity
Robert Rosenburg - Electric Motor Repair
Delmar - Electricity III

## Install a Four Point Starter with Speed Control

Speed control of D.C. motors can be effected in a number of ways depending upon the type of motor and the condition of load. The speed of shunt and compound motors, for instance, can be varied by means of a rheostat in the shunt field circuit. Speed of series motors can be varied by controlling the series field. However, considerable speed variation of all types of D.C. motors can be obtained by control in the armature circuit.

There are as many designs of this type of apparatus as there are manufacturers but the basic function of each is the same. There are two different types of manual speed controllers commonly used with direct current shunt and compound motors.

1. Above normal speed controllers.
2. Above and below normal speed controllers.

Let us consider the above normal speed controller first. This controller is used for above normal variable speed motor control and includes the field resistor as part of the controller.

The controller illustrated in Figure 1 really has three functions.

1. To accelerate the motor to rated speed by reducing the resistance in the armature circuit.
2. To limit the current surge in the armature circuit to a safe value.

The connections for the four point speed regulating rheostat are similar to that of a standard four point starting box, except that the field resistance is incorporated in the same box.

This type of controller has two rows of contact buttons mounted on a slate panel. The top row of contact buttons are relatively small in size and connect to a tapped resistor in the field circuit. The bottom row of contact buttons are larger in size and connect to a tapped resistor in the armature circuit.

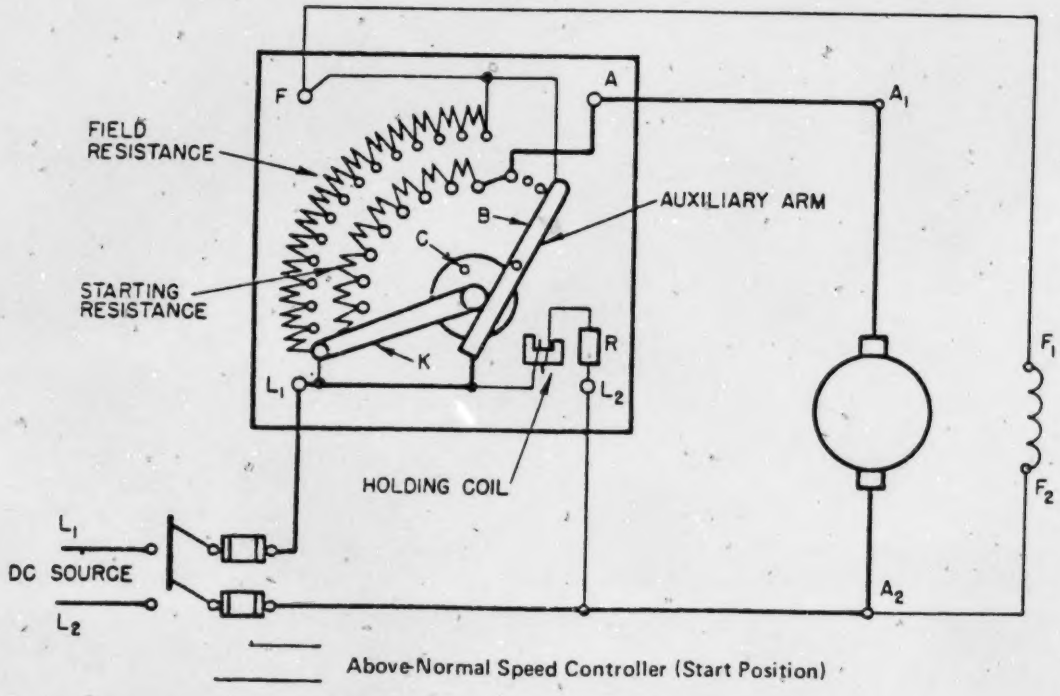
This type of starter has a special handle, actually two arms, one under the other. When the handle is moved up, both arms are interlocked. After the handle is brought to the last contact point, the holding coil maintains in position the arm which contacts the armature resistance points. If it is desired to increase the speed above normal, the handle is moved in a counter-clockwise direction. This moves only the arm contacting the field resistance and cuts in resistance in the field circuit.

When the arm is in off position the shunt field resistance is shorted out by means of an auxiliary contact located on the face plate. This contact is movable so that when the handle is rotated to the uppermost position the auxiliary contact opens the shorted field resistance and allows it to be used in the field circuit. At the same time the holding coil is connected in the circuit.

The object of shorting the field resistance is to prevent its use until all the armature resistance has been cut out.

To start motor the handle is moved to the first contact point and a circuit is formed from one side of the line to the handle through all the armature resistance, through the armature circuit and back to the other side of the line. Also, a circuit is completed from the first contact button through the auxiliary contact to the field terminal, through the shunt field, and back to the line. After the motor accelerates and the handle is brought to the last contact, the auxiliary contact opens and permits the field resistance to enter the circuit and also closes the holding coil circuit which holds the handle in position. If increased speed is desired, the arm which contacts the field resistance is moved in a counterclockwise direction, inserting resistance in the shunt field circuit. When the main switch is opened, a coiled spring at the base of the handle returns it to "off" position.

Figure 1



Another combination starter and speed regulator which operates on the same principle as the previous controller but whose construction is somewhat different is illustrated in Fig. 2. This is a typical above and below normal speed controller. There is one arm used in this controller which makes connections with two rows of contacts. The contacts of the lower row are relatively larger in size and are connected to a tapped resistor used in the armature circuit. The contacts of the upper row are relatively small in size and are connected to a tapped resistor used in the shunt field circuit. The contacts are mounted on the front of a slate panel while the armature and field resistor are housed in a ventilated box in back of the slate panel.

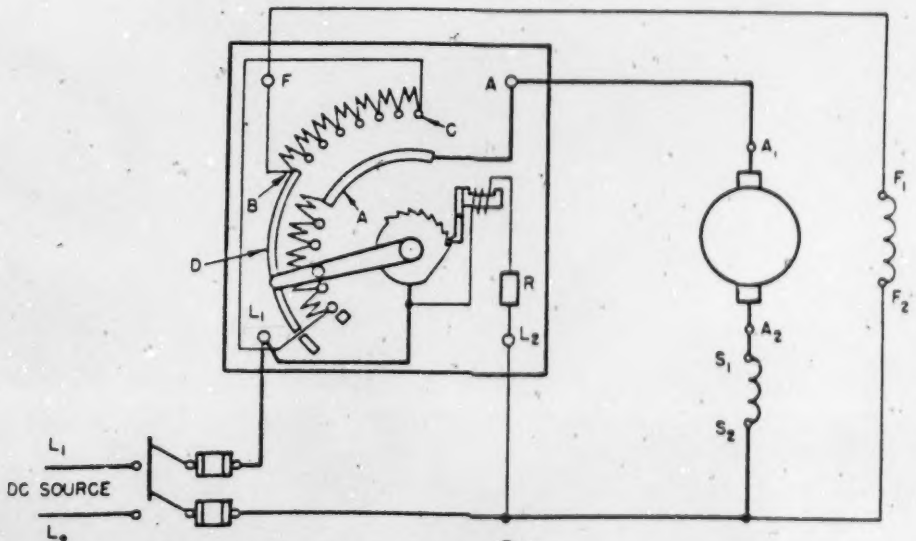
Once the arm is set on any contact point it will lock in that position until moved to some other contact point. This is done in a gear and latch system operated in conjunction with the holding coil.

At slow speed the current passes through the armature resistors therefore the armature resistors have to be of large size to radiate the heat caused by the large wattage losses.

In Fig. 2, if the arm is set in any position below point "A" this will cause the motor to run in below normal speed. If the arm is set in any position above point "A" this will cause the motor to run at above normal speed. A closer study of the circuitry used in this controller will bear this out. At any point below "A" the armature resistors are used in the armature circuit and full field strength is applied to the motor.

At point "A" the motor would run at rated speed. At this point the armature resistance would be out of the circuit and the maximum amount of current would be flowing through the shunt field. If the arm is set at any position above point "A" the motor will run above rated speed because the shunt field would be weakened and full line voltage applied to the armature circuit.

When the motor is to be shut down, simply open the line switch. The holding coil will then release the gear and latch device and the reset spring can then return the arm to the "off" position. Before closing line switch always be sure the arm is in the "off" position.




Above and Below-Normal Speed Controller (Set for Below-Normal Speed)

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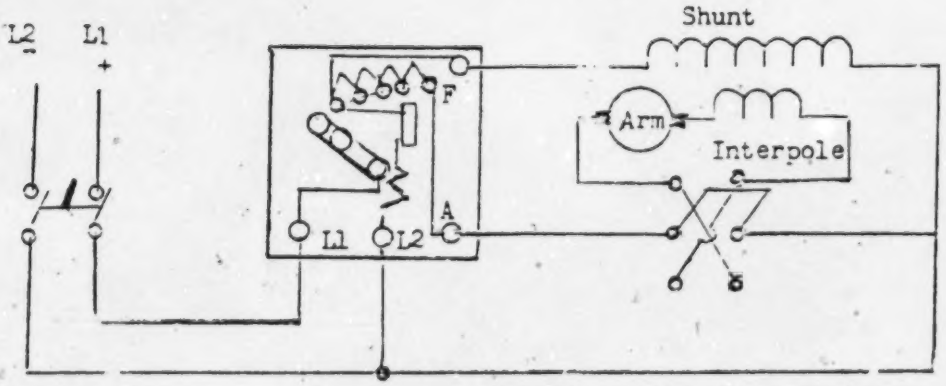
Direct Current Motor Controls

Information Sheet 5
Page 1 of 1

The Use of a D.P.D.T. Switch for Reversing Shunt Wound D.C. Motor

Reversing of D.C. motors requires several flows of current through either the armature or the field. The usual method for reversal consists of some type of switch assembly which will reverse the connections to the armature, such as the double pole, double-throw switch in Fig. 1.

Fig. 1 - D.P.D.T. Switch for Reversing Shunt-Wound D.C. Motor




A shunt motor connected to a four-point box and reversing switch

In reversing D.C. Shunt Motors with interpoles it is necessary to reverse the current flow through both the armature and interpoles as a unit. Reversing the armature leads without the interpole will cause the motor to have incorrect interpole polarity, which will make the motor run excessively hot and will produce sparking at the brushes.

To reverse the motor, the main switch must be opened first. THIS IS IMPORTANT. This will cause the motor to come to a complete stop before attempting to operate it in the reverse or opposite direction.

At this time it might be well to study the diagram in Fig. 1. Please observe that the double pole double throw switch is located in the circuit beyond the four-point starter and is connected in the armature and interpole circuit.

The reversing switch can also be used with three-point starting boxes, and can be used to reverse series shunt, and compound motors.

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Direct Current Motor Controls

Job Sheet 5
Page 1 of 4

Wire a D.P.D.T. Switch for Reversing a Shunt Wound D.C. Motor

Objective:

1. To understand the use of a D.P.D.T. switch and the circuits involved in reversing a shunt wound D.C. motor.
2. Ability to properly connect a D.P.D.T. switch on conjunction with a four-point starter in a circuit for reversing a shunt wound D.C. motor.
3. Ability to apply N.E.C. requirements to the installation.

Materials:

A four-point D.C. starting box; double pole; double throw switch; D.C. motor; disconnecting means; conduit and fittings; wire or cable; overload protective device for motor used and all other necessary materials to be determined by the student.

Explanation:

Whenever a shunt wound D.C. motor is to be reversed, the current in the armature circuit must be reversed. The usual method for reversing consists of some type of switch assembly which will reverse the connections to the armature, such as the Double Pole, Double Throw Switch, Fig. 1, Information Sheet 5.

Procedure:

1. Read Information Sheet No. 5 for Direct Motor Controls.
2. Have instructor assign motor and classification of service.
3. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent protection from feeder to motor.
4. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C.
5. Submit for approval a wiring diagram showing all connections from feeder terminal to motor.
6. Proceed to mount equipment in area designated by your instructor.
7. If equipment is already mounted, submit diagrams called for in Steps 3 through 5 and check the existing installation for proper size equipment, conduit, wire fuses, and overcurrent protective devices.
8. Check disconnects, reversing switch and starting box for the following:
   a. Contact surfaces (i.e. clean, worn, pitted, alignment).
   b. Correct and smooth operation of moving parts (no binding).
   c. Check operating arm on face plate controller for spring reset. (be sure arm returns to "off" position when holding coil is de-energized).
   d. Check for correct voltage.

e. Check resistance unit in starting box for opens and grounds.

f. Check "no voltage release coil" in starting box for continuity and condition.

g. Check equipment for broken or cracked bases.

h. Check starting box for proper internal connections, and conditions of resistance tubes and wiring.

i. Check for correct overload protective device for motor used.

9. Identify all component parts of the equipment used and explain the function of each. Submit to your instructor for approval.

10. Proceed to wire equipment and control as per your approved wiring diagram.

11. Check motor for the following:

a. Proper voltage.

b. Bearings properly lubricated, if oil ring type lubrication, be sure oil ring turns freely when motor shaft is rotated.

c. Armature turns freely without squeaking or bumping.

d. Commutator free from carbon deposits, glistening but dark in color. (chestnut brown).

e. Brushes bear evenly across their whole surface with proper tension.

f. Keyed pulley is tight on motor shaft, (if used).

g. Belt is adjusted to proper tension if motor drives a machine by belting.

12. Check all terminal connections for tightness. All splices shall be mechanically and electrically tight.

13. Have your instructor check the completed installation and secure his approval for energizing the circuit.

14. Be sure D.P.D.T. switch is closed in either the forward or reverse position.

Note: This is important.

Note: If instructor directs a new job - i.e. wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or the switchboard.

Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any place where the work is done contrary to the N.E.C. regulations.

The wiring must be done in a workmanlike manner and the conductors used must be of proper type and proper carrying capacity.

15. Energize circuit to four-point starting box.

    Note: If a field rheostat is used in the shunt field circuit be sure that the resistance has been cut out of the shunt field circuit. This is important because the shunt field could be weakened to a point where the motor will tend to "run" away, and destroy itself.

16. Move the operating arm of the four-point starting box step by step over the contacts, waiting a few seconds on each contact for the motor speed to accelerate. If this process is performed too quickly the motor may be damaged by excessive current; if too slowly, the starting resistors may be damaged. If the motor fails to start on the first step move promptly to the second step and if necessary to the third, but no farther. If no start is made when the third step is reached, allow the operating handle to return to off position, and look for faulty connections, overload on motor, etc.

17. If no fault is encountered in moving from the first contact to the third contact and the motor accelerates in speed, continue moving handle until last contact is reached. At this point the holding coil will retain the movable arm in run position.

18. With the movable arm in run position and the motor running, open disconnecting means. Movable arm should fall back to off position. This is important. If it does not, check and correct fault.

19. If a field rheostat is used in the shunt field circuit cut out resistance in the shunt field and re-energize circuit to four-point starting box and check start and run operation. Be sure that the motor bearings are being properly lubricated and that the motor is running smoothly and quietly. If it does not, check with your instructor.

20. De-energize the circuit.

21. Reverse position of D.P.D.T. reversing switch and repeat Steps 15 through 20.

22. De-energize the circuit and install a D.C. ammeter in the motor circuit. Be sure this ammeter is of suitable range for the current rating of the D.C. motor. This can be installed at the four-point starter. Be sure that the meter is protected during the high starting current period.

23. Install a D.C. voltmeter of suitable range in the motor circuit. This can also be installed at the four-point starting box.

24. Have your instructor check your meter circuits and at this time secure his permission to re-energize the circuit.

25. Repeat Steps 16 and 17 and take current reading of the motor and record.

26. Check this current value with name plate current rating of motor.

27. Take a voltage reading of the voltmeter. This reading should correspond to the voltage rating on the name plate of motor. Record same.

28. Check the speed in R.P.M. of motor with the use of a speed counter and record.

    Note: This should be done with field rheostat resistance cut out of the shunt field circuit.

29. Check this value in R.P.M. with name plate R.P.M. rating of motor.
30. De-energize circuit.
31. If there is any serious disagreement in the value of readings taken and data secured from name plate on motor, check with your instructor.
32. All readings and data taken should be recorded in suitable form and turned in to your instructor for evaluation, and permission secured to disconnect meters from the motor circuits.
33. After meters have been disconnected and returned, replace any connections that may have been removed when installing meters in the circuit.

Questions:

1. Why was a D.P.D.T. switch used in this D.C. shunt motor circuit and why was it placed in the armature circuit?
2. Is there any other way of reversing a shunt connected motor, if so, explain how this can be accomplished.
3. Was there any difference between the forward and reverse operation of this motor?
4. Did your meters indicate any difference in the operation between forward and reverse?
5. What are the N.E.C. requirements in regard to the installation of a D.P.D.T. switch for reversing a D.C. motor?
6. Can a D.P.D.T. switch be used for reversing a compound connected D.C. motor? If so, submit a diagram showing how this can be accomplished.

References:

Croft - American Electrician's Handbook
National Electrical Code
Loper - Direct Current Electricity
Robert Rosenburg - Electric Motor Repair
Delmar - Electricity III
McIntyre - Electric Motor Control Fundamentals

CONNECTICUT STATE VOCATIONAL SCHOOLS

Direct Current Motor Controls

Job Sheet 6
Page 1 of 4

# Wire Magnetic D.C. Starter with Four-Step Acceleration for Large Motors

## Objective:

1. To properly wire a four-step acceleration starter.
2. Ability to properly connect a four-step acceleration starter.
3. Ability to apply N.E.C. requirements for the installation.

## Materials:

A four-point acceleration starter; D.C. Motor; disconnecting means; conduit and fittings; wire or cable; overload protective device for motor used and all other necessary materials to be determined by student.

## Explanation:

Whenever large motors are to be started, one method of doing this is to use an acceleration starter. This job involves the use of a four-step acceleration starter. Please read Information Sheet #7 on Direct Motor Controls.

## Procedure:

1. Have instructor assign motor and classification of service.
2. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent device from feeder to motor.
3. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C.
4. Submit for approval a wiring diagram showing all connections from feeder terminal to motor.
5. Proceed to mount equipment in area designated by your instructor.
6. If equipment is already mounted, submit diagrams called for in Steps 2 through 4 and check the existing installation for proper size equipment, conduit, wire, fuses, and overcurrent protective devices.
7. Check disconnects and accelerating starter for the following:
   a. Contact surfaces (i.e. clean, worn, pitted, alignment).
   b. Correct and smooth operation of moving parts (no binding).
   c. Check accelerating step mechanisms, if dash-pot controlled check level of oil in dash-pot. If mechanically timed check this mechanism to be sure it operates properly.
   d. Check holding coils, and accelerating mechanism coils for opens.
   e. Check for correct voltage.
   f. Check resistance unit for opens and grounds.
   g. Check for broken and cracked bases.
   h. Check starter for proper internal connections (panel wiring).
   i. Check for correct overload protective device for motor used.

8. Identify all component parts of this control and explain the function of each. Submit to your instructor for approval.
9. Proceed to wire equipment and control as per your approved wiring diagram.
10. Check motor for the following:
    a. Proper voltage.
    b. Bearings well lubricated, if oil ring type lubrication, be sure oil ring turns freely when motor shaft is rotated.
    c. Armature turns freely without squeaking or bumping.
    d. Commutator free from carbon deposits, glistening but dark in color (chestnut brown).
    e. Brushes bear evenly across their whole surface with proper tension.
    f. Keyed pulley is tight on motor shaft, (if used).
    g. Belt is adjusted to proper tension if motor drives a machine by belting.
11. Check all terminal connections for tightness. All splices shall be mechanically and electrically tight.
12. Have your instructor check the completed installation and secure his approval for energizing the circuit.

    Note: If your instructor directs a new job -- i.e. wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or switchboard. Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any place where the work is done contrary to N.E.C. regulations. The wiring must be done in a workmanlike manner and the conductors used must be of proper type and proper carrying capacity.

13. Energize circuit to accelerating starter.

    Note: If a field rheostat is used in the shunt field circuit <u>be sure that the resistance has been cut out of the shunt field circuit</u>. This is important because the shunt field could be weakened to a point where the motor will tend to run away and destroy itself.

14. Push start button, this energizes control relay M. This relay closes the main contacts. The motor should start and run at slow speed. The accelerating relays and contacts will begin closing as the motor accelerates in speed until all relays are closed and the armature resistance is shortened and eliminated from the armature circuit. At this point the motor should have attained rated speed.

    If the motor fails tc start on first or second accelerating step, push <u>stop</u> button and look for faulty connections, overload on motor, etc.

15. If no fault is encountered as starter is energized and motor is operating correctly, open disconnecting means. All contacts in accelerating starter should open. <u>This is important</u>. If it does not, check and correct fault.

16. If a field rheostat is used in the shunt field circuit cut out resistance in the shunt field circuit and re-energize circuit to acceleration starter and check start and run operation. Be sure that the motor bearings are being properly lubricated and that motor is running smoothly and quietly with no sparking at commutator. If it does not operate properly, check with your instructor.

17. De-energize the circuit and install a D.C. ammeter in the motor circuit. Be sure this ammeter is of suitable range for the current rating of the D.C. motor. This can be installed in the circuit between the automatic starter and the D.C. motor. Be sure the meter is protected during the high starting current period.

18. Install a D.C. voltmeter of suitable range in the motor circuit.

19. Have your instructor check your meter circuits and secure his permission to re-energize the circuit.

20. Repeat steps 13 and 14 and take current reading of motor and record.

21. Check this current value with name plate rating of motor.

22. Take a voltage reading of the voltmeter. This reading should correspond to the voltage rating on the name plate of motor. Record same.

23. Check the speed in R.P.M. of motor with the use of a speed counter and record.

    Note: This should be done with the field rheostat resistance cut out of the shunt field circuit.

24. Check this value in R.P.M. with name plate R.P.M. rating of motor.

25. De-energize circuit.

26. If there is any serious disagreement in the value of reading taken and data secured from name plate on motor, check with your instructor.

27. All readings and data should be recorded in suitable form, and turned in to your instructor for evaluation, and permission secured to disconnect meters from the circuit.

28. After meters have been disconnected and returned, replace any connections that may have been removed when installing meters in the circuit.

Questions:

1. Describe the construction and explain the operation of a four-step acceleration starter.

2. Why is it called an acceleration starter?

3. What is a counter e.m.f. controller? Explain in detail.

4. What is a lockout controller? How does this differ from a counter e.m.f. controller?

5. What are the N.E.C. rules that apply to fuse protection for D.C. motors? State the rule, article number, and section number.

6. What are the N.E.C. requirements in regard to under voltage release of D.C. motors?

References:

Croft - American Electrician's Handbook
National Electrical Code
Loper - Direct Current Electricity
Robert Rosenburg - Electric Motor Repair
Delmar - Electricity III
McIntyre - Electric Motor Control Fundamentals

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Direct Current Motor Controls

Information Sheet 7
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## Wire Dynamic Braking Circuit

Purpose:

In some installations there is a need for quick stopping and immediate reversal of rotation. "Dynamic braking" is a method for quickly using up the mechanical energy of motion of the armature and its mechanical load after the armature circuit is opened. This is done by connecting a resistor across the armature at the instant the armature circuit is disconnected. The disconnected armature, rotating on its own momentum, is cutting flux and acting as a generator. The generated current quickly dissipates this mechanical energy by heating the resistor and thus stops the motion quickly.

ELEMENTARY DIAGRAM COUNTER E.M.F. CONTROLLER

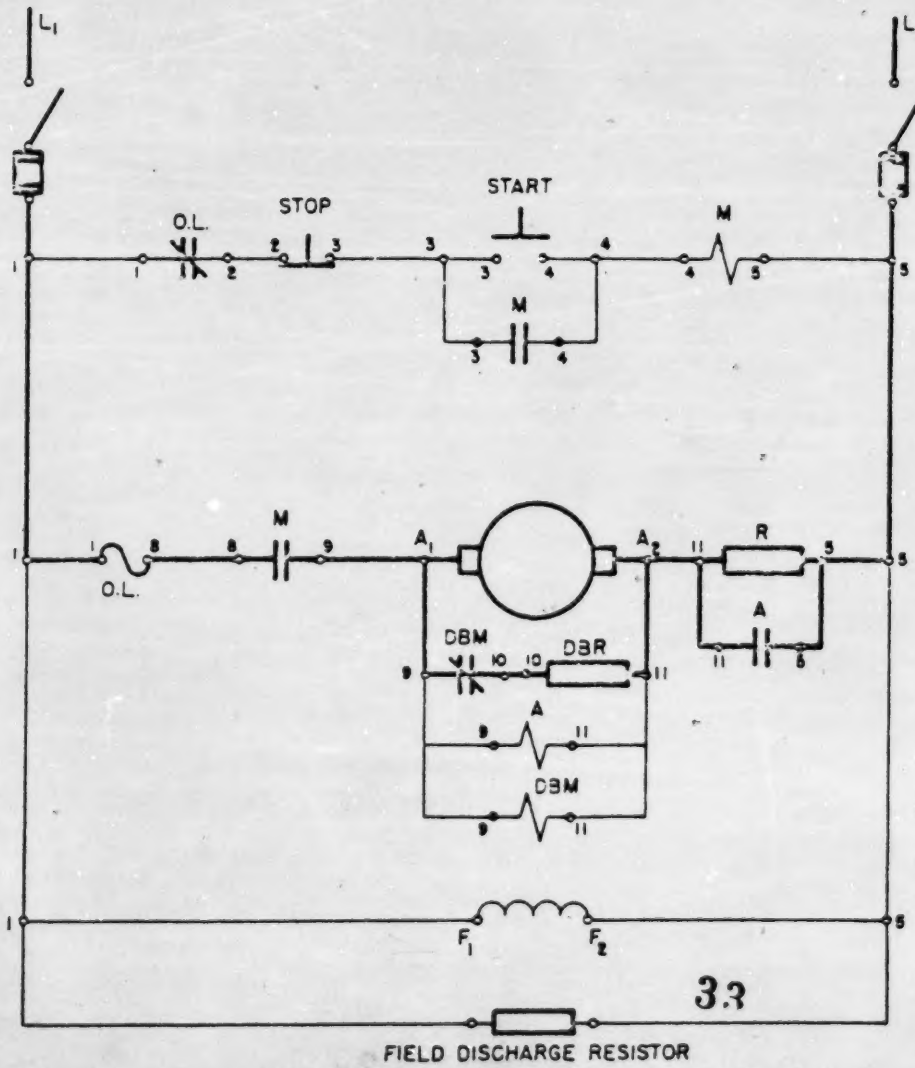
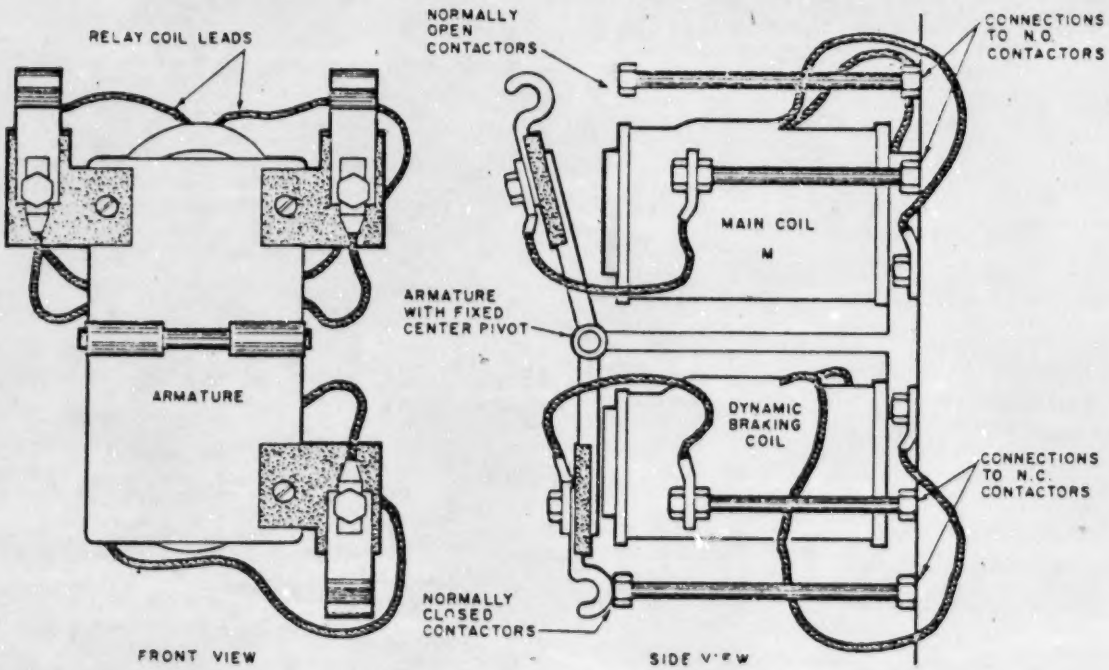


Figure 1 shows how dynamic braking facilities can be incorporated with a counter e.m.f. controller.

Relay coil M and dynamic braking coil (DBM, 6-7) operates as one mechanism. When the start button is pressed, coil M closes the normally open contactors, pulling open the one set of D.B.M. contactors. As the motor accelerates, relay coil A shunts out the current limiting resistor. Although the D.B.M. coil is now energized by full line voltage, Coil M has already tipped the pivoted armature clockwise, opening the D.B.M. contact. Coil D.B.M. is not strong enough to bring the armature back to normally open position so the D.B.M. contactors remain open while the motor operates normally.

When the stop button is pressed, coil M releases the pivot relay armature, Fig. 2. The shunt field of the motor is still connected to the line. so the rotating armature of the motor generates a current that keeps coil D.B.M. energized. Coil D.B.M. is now able to pull contactors D.B.M. to their normally closed position coil M being de-energized. With D.B.M. contactors closed, the dynamic braking resistor is connected directly across the motor armature. Now the motor armature acting as a generator, converts its mechanical energy into electrical energy which is quickly dissipated in the D.B.R. resistor as the motor armature comes to a quick stop. Coil A releases contactors A reinserting the current-limiting resistor in series with the armature.

Fig. 2




DIRECT CURRENT CONTACTOR ASSEMBLY

CONNECTICUT STATE VOCATIONAL SCHOOLS

Direct Current Motor Controls

Job Sheet 7
Page 1 of 4

# Wire Dynamic Braking Circuit

Objective:

1. To properly wire a dynamic braking circuit.
2. Ability to properly install a dynamic braking circuit in a counter e.m.f. starter.
3. Ability to apply N.E.C. requirements to the installation.

Materials:

A counter e.m.f. starter with reversing and dynamic braking; a D.C. motor; disconnecting means; conduit and fittings; wire or cable; overload protective device for motor used and all other necessary materials to be determined by students.

Explanation:

Whenever large motors are to be reversed, dynamic braking must be incorporated into the controlling device. This allows the motor to stop a lot faster, thereby making the time the motor can be reversed a lot faster. This increases the efficiency of the industrial operation.

Procedure:

1. Have your instructor assign motor and classification of service.
2. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent device from feeder to motor.
3. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C.
4. Submit for approval a wiring diagram showing all connections from feeder to terminal to motor.
5. Proceed to mount equipment in area designated by your instructor.
6. If equipment is already mounted, submit diagrams called for in Steps 2 through 4 and check the existing installation for proper size equipment, conduit, wire, fuses, and overcurrent protective devices.
7. Check disconnects and accelerating starter for the following:
   a. Contact surfaces (i.e. clean, worn, pitted, alignment).
   b. Correct and smooth operation of moving parts (no binding).
   c. Check accelerating stop mechanism, if dash-pot controlled check level of oil in dash-pot. If mechanically timed check the mechanism to be sure it operates properly.
   d. Check holding coils, and accelerating mechanism coils for opens.
   e. Check for correct voltage.
   f. Check resistance unit for opens and grounds.

g. Check for broken and cracked bases.
h. Check starter for proper internal connections (panel wiring).
i. Check for correct overload protective device for motor used.

8. Identify all component parts of this control and explain the function of each. Submit to your instructor for approval.

9. Proceed to wire equipment and control as per your approved wiring diagram.

10. Check motor for the following:

a. Proper voltage.
b. Bearings well lubricated, if oil ring type lubrication, be sure oil ring turns freely when motor shaft is rotated.
c. Armature turns freely without squeaking or bumping.
d. Commutator free from carbon deposits, glistening but dark in color (chestnut brown).
e. Brushes bear evenly across their whole surface with proper tension.
f. Keyed pulley is tight on motor shaft, (if used).
g. Belt is adjusted to proper tension if motor drives a machine by belting.

11. Check all terminal connections for tightness. All splices shall be mechanically and electrically tight.

12. Have your instructor check the completed installation and secure his approval for energizing the circuit.

Note: If your instructor directs a new job -- i.e. wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or switchboard. Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any place where the work is done contrary to N.E.C. regulations. The wiring must be done in a workmanlike manner and the conductors used must be of proper type and proper carrying capacity.

13. Energize circuit to counter e.m.f. starter.

Note: If a field rheostat is used in the shunt field circuit be sure that the resistance has been cut out of the shunt field circuit. This is important because the shunt field could be weakened to a point where the motor will tend to "run" away and destroy itself.

14. Push start button, this energizes control relay M. This relay closes the main contacts. The motor should start and run at slow speed. As the motor accelerates, relay coil A shunts out the current limiting resistor by closing contacts A (Fig. 1, INF. Sheet 8), and full line voltage is applied across the armature. The motor should now operate normally.

15. Press stop button, coil M should release the pivoted relay armature. The shunt field of the motor will still be energized so the rotating

armature of the motor generates a current that keeps coil D.B.M. energized. Coil D.B.M. is now able to pull D.B.M. contactors to their normally closed position. Coil M should de-energize. With D.B.M. contactors closed, the dynamic braking resistor is connected directly across the motor armature. Now the motor armature acting as a generator converts its mechanical energy into electrical energy which is quickly dissipated in the D.B.R. resistor, and the motor armature comes to a quick stop. Coil A releases contactors A, re-inserting the current-limiting resistor in series with the armature.

16. If a field rheostat is used in the shunt field circuit cut out resistance in the shunt field circuit and re-energize circuit to acceleration starter and check start and run operation. Be sure that the motor bearings are being properly lubricated and that the motor is running smoothly and quietly with no sparking at commutator. If it does not operate properly, check with your instructor.
17. De-energize the circuit and install a D.C. ammeter in the motor circuit. Be sure this ammeter is of suitable range for the current rating of the D.C. motor. This can be installed in the circuit between the automatic starter and the D.C. motor. Be sure the meter is protected during the high starting current period.
18. Install a D.C. voltmeter of suitable range in the motor circuit.
19. Have your instructor check your meter circuits and secure his permission to re-energize the circuit.
20. Repeat steps 13 and 14 and take current reading of motor and record.
21. Check this current value with name plate rating of motor.
22. Take a voltage reading of the voltmeter. This reading should correspond to the voltage rating on the name plate of the motor. Record same.
23. Check the speed in R.P.M. of motor with the use of a speed counter and record.

    Note: This should be done with the field rheostat resistance cut out of the shunt field circuit.
24. Check this value in R.P.M. with the name plate R.P.M. rating of motor.
25. De-energize circuit.
26. If there is any serious disagreement in the value of reading taken and data secured from name plate on motor, check with your instructor.
27. All readings and data should be recorded in suitable form and turned in to your instructor for evaluation, and permission secured to disconnect meters from the circuit.
28. After meters have been disconnected and returned, replace any connections that may have been removed when installing meters in the circuit.

Questions:

1. Describe the construction and explain the operation of a counter e.m.f. starter with dynamic braking.

2. Why is it called a counter E.M.F. starter?

3. What are the N.E.C. rules that apply to fuse protection for D.C. motors? State the rule, article number, and section number.

4. Explain what is meant by "dynamic braking" in motor control work.

References:

Croft - American Electrician's Handbook
National Electrical Code
Loper - Direct Current Electricity
Robert Rosenburg - Electric Motor Repair
Charles Siskind - Electrical Control Systems in Industry

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Direct Current Motor Controls

Job Sheet 8
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## Wire Magnetic D.C. Starter with Four Step Acceleration And Reversing With Dynamic Braking

Objective:

1. To properly wire a four step acceleration starter with reversing and dynamic braking.
2. Ability to properly connect a four step acceleration starter with reversing and dynamic braking.
3. Ability to apply N.E.C. requirements to the installation.

Materials:

A four point acceleration starter with reversing and dynamic braking; D.C. motor; disconnecting means; conduit and fittings; wire or cable; overload protective device for motor used, and all other necessary materials to be determined by students.

Explanation:

Whenever large motors are to be started and reversed an accelerating starter with dynamic braking is used. Please read Information Sheets 7 and 8 on "Direct Motor Controls". Read bulletin supplied with your particular starter and follow manufacturer's wiring diagram, study this diagram and familiarize yourself with the starting, running and reversing procedures.

Procedure:

1. Have instructor assign motor and classification of service.
2. Submit for approval a line diagram showing the sizes of equipment, wire, and overcurrent device from feeder to motor.
3. Submit for approval a conduit diagram showing all equipment, sizes of conduit and wire sizes as governed by N.E.C.
4. Submit for approval a wiring diagram showing all connections from feeder terminal to motor.
5. Proceed to mount equipment in area designated by your instructor.
6. If equipment is already mounted, submit diagrams called for in Steps 2 through 4 and check the existing installation for proper size equipment, conduit, wire, fuses, and overcurrent protective devices.
7. Check disconnects and accelerating starter for the following:
   a. Contact surfaces (i.e. clean, worn, pitted, alignment).
   b. Correct and smooth operation of moving parts (no binding).
   c. Check accelerating step mechanism, if dash-pot controlled, check level of oil in dash-pot. If mechanically timed check this mechanism to be sure it operates properly.

d. Check holding coils, and accelerating mechanism coils for opens.
e. Check for correct voltage.
f. Check resistance unit for opens and grounds.
g. Check for broken and cracked bases.
h. Check starter for proper internal connections (panel wiring).
i. Check for correct overload protective device for motor used.

8. Identify all component parts of this control and explain the function of each. Submit to your instructor for approval.

9. Proceed to wire equipment and control as per your approved wiring diagram.

10. Check motor for the following:

a. Proper voltage.
b. Bearings well lubricated, if oiled ring type lubrication, be sure oil ring turns freely when motor shaft is rotated.
c. Armature turns freely without squeaking or bumping.
d. Commutator free from carbon deposits, glistening but dark in color (chestnut brown).
e. Brushes bear evenly across their whole surface with proper tension.
f. Keyed pulley is tight on motor shaft, (if used).
g. Belt is adjusted to proper tension if motor drives a machine by belting.

11. Check all terminal connections for tightness. All splices shall be mechanically and electrically tight.

12. Have your instructor check the completed installation and secure his approval for energizing the circuit.

Note: If your instructor directs a new job - i.e. wire up a motor and control completely - run a circuit in approved conduit work or cable to the location of the motor from some suitable panel box or switchboard. Otherwise, examine the wiring of the feeder circuit to the point to which the motor is to be connected. Note any place where the work is done contrary to N.E.C. regulations. The wiring must be done in a workmanlike manner and the conductors used may be of proper type and proper carrying capacity.

13. Energize circuit to accelerating starter.

Note: If a field rheostat is used in the shunt field circuit be sure that the resistance has been cut out of the shunt field circuit. This is important because the shunt field could be weakened to a point where the motor will tend to "run" away and destroy itself.

14. Follow manufacturer's instruction bulletin for the particular starter that you are using.

15. Push forward button. The motor should start and run at slow speed. The accelerating relays and contacts will begin closing as the motor accelerates in speed until all relays are closed and the armature resistance is shorted and eliminated from the armature circuit. At this point the motor should have attained rated speed. Press stop button and check dynamic braking circuit, motor should come to a quick stop. Repeat above procedure in the reverse direction by depressing reverse button.
16. If a field rheostat is used in the shunt field circuit cut out resistance in the shunt field circuit and re-energize circuit to acceleration starter and check start and run operation. Be sure that the motor bearings are being properly lubricated and that the motor is running smoothly and quietly with no sparking at commutator. If it does not operate properly, check with your instructor.
17. De-energize the circuit and install a D.C. ammeter in the motor circuit. Be sure this ammeter is of suitable range for the current rating of the D.C. motor. This can be installed in the circuit between the automatic starter and the D.C. motor. Be sure the meter is protected during the high starting current period.
18. Install a D.C. voltmeter of suitable range in the motor circuit.
19. Have your instructor check your meter circuits and secure his permission to re-energize the circuit.
20. Repeat steps 13 and 14 and take current reading of motor and record.
21. Check this current value with name plate rating of motor.
22. Take a voltage reading of the voltmeter. This reading should correspond to the voltage rating on the name plate of the motor. Record same.
23. Check the speed in R.P.M. of motor with the use of a speed counter and record.

    Note: This should be done with the field rheostat resistance cut out of the shunt field circuit.
24. Check this value in R.P.M. with the name plate R.P.M. rating of the motor.
25. De-energize circuit.
26. If there is any serious disagreement in the value of reading taken and data secured from name plate on motor, check with your instructor.
27. All readings and data should be recorded in suitable form and turned in to your instructor for evaluation, and permission secured to disconnect meters from the circuit.
28. After meters have been disconnected and returned, replace any connections that may have been removed when installing meters in the circuit.

Questions:

1. Describe in detail how "dynamic braking" is applied to this circuit.
2. Name at least three types of D.C. automatic starters.
3. How is reversing accomplished in this type of controller?

References:

Croft - American Electrician's Handbook
National Electrical Code
Loper - Direct Current Electricity
Robert Rosenburg - Electric Motor Repair
Delmar - Electricity III